DIVISION OF SILVICS

United States Forest Service

TRANSLATION

No. 314

RAPPORT UITGEBRACHT DOOR DE DIRECTIE DER NEDERLANDSCHE HEIDEMAATSCHAPPIJ AAN DEN MINISTER VAN BINNENLANDSCHE ZAKEN, OVER ONTTREKKING VAN WATER DOOR DE PLANTEN AAN DEN BODEM

(REPORT OF THE DIRECTOR OF NEDERLANDSCHE HEIDEMAATSCHAPPIJ TO THE MINISTER OF THE INTERIOR REGARDING THE WITHDRAWAL OF WATER FROM THE SOIL BY PLANTS)

FROM

TIJDSCHRIFT DER NEDERLANDSCHE HEIDEMAATSCHAPPIJ
13 (2): 45-70, 1901.

Translated from the Dutch,
By: Michel Mok,
October, 1937.

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(Rapport uitgebracht door de Directie der Nederlandsche Heidemaatschappij aan den Minister van Binnenlandsche Zaken, over onttrekking van water door de planten aan den bodem)

FROM

TIJDSCHRIFT DER NEDERLANDSCHE HEIDEMAATSCHAPPIJ
13(2): 45-70. 1901.

CONSUMPTION OF WATER BY PLANTS AND ITS LOSS THROUGH EVAPORATION

The Significance of water to plants. Water plays a significant role in plant life. It transports upward mineral salts withdrawn from the soil by the roots which then form organic substances under the influence of light in leaves. On the other hand water transports substances to places where they are used either directly for growth or where they are stored as reserve substances.

The great importance of water to plant organisms is demonstrated by the fact that it constitutes from 70 to 80 percent of the weight of mature plant parts and often 90 percent of young organs.

Therefore, it is a vital necessity for plants; an indispensable component of each living cell which would be unable to function without it; it is direct nourishment since it is the only source of hydrogen in plants.

Without a steady water supply, maintained by the transpiration stream, regular growth becomes impossible since also the rest of indispensable substances necessary for growth, such as air and nutrients, would fail to become fully effective.

If a plant suffers for lack of water it is prevented from availing itself of nutrients in the soil no matter how abundantly such nutrients are present, since as is known, according to the law of minimum, there exists a certain relation between each of these factors. For, if one of these factors with regard to another one function insufficiently or does not exist, it will prevent other factors from becoming fully effective.

Therefore, the amount of our crop depends very much on the amount of water which plants are able to consume during the period of greatest growth.

No matter how well the soil is fertilized, if it contains no water for the plants, the crop will be negligible or will fail altogether.

For example, due to the withdrawal of ground water there has been a steady crop regress on small potato patches in our dunes in spite of intensive fertilization. True, intensive fertilization and preparation of the soil may counterbalance a dry soil but as experience has proved these measures are mere paliatives and only partly compensate lack of water.

But just as too small a water content can have a detrimental effect on growth, too large an amount of water also may have an influence not less detrimental since it prevents aeration of the soil.

For this reason some people originally expected beneficial effects from the withdrawal of water since it was their opinion that soils which were lying too low could then be cultivated more successfully.

Transpiration. Transpiration and the ascent of water in plants is made possible by the fact that air in the tissues of plants contains more moisture than the external atmosphere. This creates a tendency to restore this disturbed equilibrium. Hence, the drier the outside atmosphere the greater the transpiration.

Meanwhile, the amount of water transpired by a plant must always be replaced; transpiration and water supply must keep step.

If during a given period evaporation exceeds absorption conditions are abnormal and plants begin to decline and die.

Von Hoehnel 1/ has given us some idea regarding the amount of water transpired by plants. According to him a large, isolated birch transpires 7,086 kg. of water in 6 months or 38 L. daily.

According to Noble, two alders about 2 years old with a leaf surface of 1-1/2 and 1-2/3 sq.m. in 90 days transpired 38,000 kg. of water or approximately 200 gr. per day per sq.m.

Different water requirements. The amount of water required by plants is, however, not the same. There are plants which transpire little which correspondingly make less demands on the moisture content of the soil and hence are able to develop on drier soil.

This greater capacity is the result of stronger pilosity of plant parts containing water or a thicker epidermis, thereby diminishing exposure of plant parts to evaporation or, such plants have a deeper root system enabling them to absorb more water.

1/ Mitteilungen aus dem Forstl. Versuchswesen Oesterreichs., vol. 2, part 3.

Such plants are called xerophytes in contrast to hydrophytes which make higher demands on the water content of a soil.

Hydrophytes usually have a shallow root system and are therefore dependent on moisture in the upper horizon.

In this respect, deeply rooted plants are in a more advantageous position since they are able to find moisture in deeper layers.

The amount of water which plants consume depends also on the amount of water in the soil. To a certain extent plants become inured to little water if the supply is diminished during their growth (accommodation capacity). There is, however, a certain limit.

Beyond this limit, i.e., if certain plants or trees are no longer able to find the minimum amount of water, they will disappear to make room for a vegetation which finds the amount of water available sufficient.

This is especially noticeable with our hydrophytes grown on low lands which are suddenly drained. As soon as draining is completed causing lowering of ground water, vegetation is changed. Xerophytes replace hydrophytes.

Intensive preparation of the soil, adding of substances having great capacity to retain water (humus), enables us to a certain degree to increase the soil water capacity artificially assuring the continued existence of plants on soils where by nature they do not belong or where their development would be retarded.

Ebermayer found that a well-developed 85-year-old _Picea excelsa_ contained approximately 1,000 l. of water in its woody parts and needles while an even-aged _Abies_ on the same site contained 1,200 l.

This expert calculated that a clover field with an average crop produces approximately 4,500 kg. of dry matter per ha. per year and that 3.1 l. of water is required for the production of 100 gr. of dry matter. This shows that such a clover field consumes annually approximately 1,395,000 kg. of water.

A beech forest on fertile soil produces annually 7,075 kg. per ha. of dry matter. On the basis of 3.1 l. of water for 100 gr. of dry matter, that would mean that a beech forest consumes annually ± 2,187,670 l. of water per ha.

This amounts to 140 mm. per ha. for the clover field and 218 mm. per ha. for the beech forest.

Evaporation from the soil. Direct evaporation withdraws much water from the soil. This increases during rising temperature, decreasing humidity, and increasing atmospheric currents. Hence, it fluctuates during the various seasons.

According to readings of the evaporimeter at the Meteorological Institute in Utrecht, the amount of water evaporated annually from a water surface averages 821 mm.1/

1/

January	12.7	mm.
February	23.3	"
March	48.9	"
April	91.7	"
May	125.9	"
June	136.7	"
July	130.4	"
August	110.5	"
September	72.0	"
October	37.9	"
November	18.9	"
December	12.1	"
Total	821.0	"

These results are the average measurements taken during 1856-1895.

A water surface loses more water by evaporation than is replaced by precipitation; evaporation from the soil, however, is less.

Experiments by the Royal Meteorological Institute 2/ revealed

2/ Annual book 1882, p. 281.

that the average annual evaporation for a period of six years, 1877-1882, for a water surface amounted to 577.6 mm.; for black earth, 457.2 mm.; and for grass, 659.7 mm.

Opinions differ with regard to the ratio between evaporation from a water surface and from a soil surface.

Based on investigations the Water Commission of Amsterdam assumes that if the evaporation from a water surface is put at 100, the evaporation from an even moist sandy surface can be put at 91.4 and from a gradually desiccating sandy surface at 61.6.

According to this report, evaporation from an open water surface is almost twice as large as that from a moist sandy surface containing at least the normal volume of 10 percent water.3/

3/ Report by the Commission, supp. 13a, p. 54.

The state commission charged with investigating these matters assumes in its report (1897) that evaporation from the soil amounts to 2/3 that from a water surface.1/ According to this, evaporation

1/ See the report of the Commission, p. 27.

from the soil near Utrecht should amount to 2/3 x 821.0 mm. = 547.33 mm.

If the soil is covered with a layer of absolutely dry sand, water underneath is hindered from evaporating; a dry sand cover protects the soil against further desiccation.

SOURCES OF WATER SUPPLY

The chief source of water in the soil is rain. The amount of rainfall varies in different localities; not only in places relatively adjacent, but also during successive years yes, even during the seasons.

In order to obtain reliable data, the amount of precipitation was measured during a long period of years and the average was calculated for the places where the measurements were taken.2/

2/ For example, the average annual precipitation during the 47-year period (1847-1895) in Utrecht amounted to 712.61 mm. divided over different months:

January	50.12	mm.
February	45.96	"
March	44.55	"
April	38.13	"
May	48.36	"
June	56.56	"
July	78.34	"
August	83.51	"
September	67.04	"
October	74.39	"
November	60.99	"
December	64.66	"
Total	712.61	mm.

Generally it can be accepted that in our country the coast has less precipitation than the interior.3/

3/

Hollum	1872-89 = 18	yrs.	684.6	mm.*
Den Helder	1852-89 = 38	"	671.2	"
Leiduin	1860-89 = 30	"	825.4	"
Scheveningen	1877-89 = 13	"	667.1	"
's-Gravenzande	1862-81 = 20	"	820.4	"
Haamstede	1866-89 = 24	"	656.3	"
O. Kappelle	1867-89 = 22	"	678.8	"
Kapelle	1869-89 = 20	"	665.7	"
Vlissingen	1855-98 = 44	"	585.3	"
Breskens	1880-89 = 10	"	677.6	"
Sluis	1879-89 = 11	"	748.4	"

* Hydrography of the Netherlands 1891. Table 1a.

It is fairly safe to assume an annual rainfall of ± 700 mm. for the interior and ± 650 mm. for the dune region.

Water supply through condensation. There is, however, still another source of water for the soil, namely, condensation of aqueous vapors in the soil. We observe this phenomenon in the absorption of aqueous vapor by soil particles and its condensation, where, due to the difference in temperature, the vapor laden atmosphere surrenders moisture to the soil.

Where the absorption of aqueous vapor is of less significance, its condensation is of more importance. This occurs especially during the night when the soil cools off through radiation. The humid atmosphere upon touching the soil cools below the dew point and aqueous vapor condensing covers and enters the soil.

The coarser the structure of soil particles the more and deeper is the penetration of air into the soil and the larger the quantity of moisture absorbed by the soil.

Specific data as to the amount of water thus made available to the soil is little known. Meanwhile, the advantageous effect of condensation, especially in coarse sandy soils, must be credited less to the direct supply of water than to keeping the soil in a fresh condition which increases the easy absorption of rain.

Water not lost by evaporation nor consumed by plants is partly retained by the soil, or, better, it accumulates as ground water. This is accomplished by the capillary action of pores between the soil particles and by adsorption of the soil particles in which each particle becomes surrounded by a thin layer of water.

The amount, however, depends on the so-called water capacity of the soil and this in turn is determined by the structure of the soil particles. What is not retained penetrates downwards where it finally is halted by a non-penetrative layer and accumulated as ground water.

The often-cited report dealing with the Amsterdam water system distinguishes 4 layers in the dunes, depending on the manner in which water occurs.

1. The lowest or "ground-water layer".
   Its depth below the surface depends on various circumstances. This layer has a maximum water capacity (37 percent).

2. The layer located immediately above the ground-water zone having a thickness of 35 cm.
   The water capacity of this layer is determined by the capillary attraction from the ground water and amounts to approximately 70 percent of the pore volume corresponding to about 26 percent of the sand volume.

3. A layer reaching almost to the surface, hence of varying thickness, depending on how far below the surface the ground water is.

    Here the water content fluctuates between 6 and 11 percent of the soil volume.

4. The top layer or evaporation zone influenced by changes in temperature.

    Water content is here very irregular.

Often too much importance has been attached to the capillary action of the soil, i.e., the rise of water from deeper layers to higher ones through fine pores in the soil. Capillary ascent of water occurs only if the water content of the lower layers is more than approximately half its maximum capacity.

If ground water is present at an accessible depth its ascent in a sandy soil is so negligible and in a very finely grained soil the rate of flow is so slow that capillary action, although beneficial can scarcely be of great significance in the consumption of water by plants.

H. Grebe 1/ with average coarse diluvial sand of which 40 to

1/ Zeitschrift f. Forst und Jagdwissenschaft 1885, p. 387.

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50 percent of the grains measured 0.3 mm.; and 50 to 54 percent 0.3 mm. found a maximum capillary ascent of 1/3 m., and with fine sand (80 percent of grains less than 1/3 mm.) a maximum ascent of 1/2 m.

Ramann 2/ with sandy soil, where 70 to 90 percent of the grains were smaller than 0.25 mm. found an ascent of ground water of ±40 cm.

2/ Forschungen der Agrikulturphysik, p. 321.

Besides capillary attraction, such as occurs in narrow capillary tubes, water in a moist soil rises also because if two soil particles are lying next to each other, one drier and one moister, water from the surface of the moister particle is transferred to the surface of the drier one. Obviously this manner of ascent is also a slow process.

Some experts believe that the ascent of water in the soil takes place only in this manner and completely refute the theory of capillary attraction.3/

3/ Nessler Jahrbuch der Agrikultur chemie 1873/74.

What portion of precipitation reaches ground water? The above question cannot be determined accurately. Different journals published very different opinions.

For example, on page 35 of supplement 12 to the much quoted report of the Amsterdam Water Commission, it is assumed, according to reports from the Hague, that 41 percent of the precipitation reaches ground water; according to the Amsterdam Water Commission, 36.6 percent; according to estimates of Dickinson and Ebermayer about 44 percent.

With these figures as a basis, accepting them as probable values, the Commission decided on 39 percent.

In supplement 13, p. 39, the Commission reports that exhaustive investigations by Ortt and van Diesen showed an apparent percentage, between 23 and 42.6. Other calculations by the Commission lead to 40 percent. In the weekly, "The Engineer" of June 30, 1900 1/ J. M. K.

1/ Numbers 17, 18, 19 of 1900 "Beitrage zur Hydrognosie der Mark Brandenburg, mit besonderer Berucksichtigung der Berliner Verhältnisse" (Contribution to the Hydrology of Brandenberg with special consideration of conditions in Berlin.

Pennink, Director of the Amsterdam Water Commission draws attention to the article by the Berlin engineer and hydrologist C. Piefke in the Journal für Gasbeleuchtung und Wasserversorgung:

"Using the works of Veitmeyer and van Soyka as a basis, he concluded that of 571 mm. of precipitation near Berlin only 20 percent reaches ground water."

The State Commission for irrigation 2/, according to two different

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2/ Verslag der Staatscomm (Report of the state Commission). p. 35.

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calculations, arrives at values of 35.1 and 43.7 percent.

The above shows that opinions vary greatly.

It is, however, worth noticing that recognized authors always arrive at lower values than previously had been considered correct.

So far as our observations are concerned the amount should not be put below 30 percent.

Thus, assuming an average precipitation of approximately ± 70 cm., there would be an annual supply per ha. of approximately ± 2,100 cu.m. to the ground water.

Rise and fall of the ground-water level. In most cases ground water accumulates in the soil on non-penetrative layers where its movement is governed by gravitation. The rapidity of movement, however, depends on the soil and is therefore greater through coarse sand than through fine sand.

The ground-water level is very irregular; in some places it is above or near the surface; at other places it is found at a very great depth.

This depth depends on the soil type, the location of layers, and the amount of water feeding the ground water. Hence, there occurs during the years a fall and rise of ground water depending on the amount of precipitation.

Ramann [1] divides the movement of ground water in Europe into two major groups.

[1] Dr. E. Ramann, Forstliche Bodenkunde und Standortslehre, p.32.

1. Regions with heavy precipitation and negligible evaporation (Alps and Upper Bavaria).

2. Regions with little precipitation and intense evaporation (North German plains).

In the first group the level of the ground water depends on the amount of precipitation.

In the second group the annual change of the ground-water level is dominated by evaporation.

In these regions to which belong the Netherlands, although proximity to the ocean and gulf stream changes the condition somewhat, we observe that ground water reaches its highest level in April at the beginning of the vegetative season. It falls from April to October to rise again until April.

The soil starts to desiccate with the advance of autumn; precipitation during this time is retained by capillary action and fails to reach the ground water.

The gradual lowering of the ground-water level during this period indicates a slow drainage to springs and streams.

Movement of ground water. No matter at what depth ground water is found, it generally follows the undulation of the upper soil surface. The presence of layers differing from the general soil structure may, however, change the course of ground water. Ground water, however, does not follow abrupt topographical changes.

There is, therefore, a steady stream of ground water towards lower levels which, in the absence of hindrances, generally follows the direction in which the terrain slopes.

A terrain completely or partly surrounded by higher elevations receives part of the ground water from higher areas, i.e., precipitations falling on higher grounds; there is a slow, steady, subterranean stream towards lower grounds where often, as in the dunes, it forms pools or lakes.

Consequently, if at a certain place ground water is withdrawn it will continue to flow to this place according to a given line of declivity.

The declivity of these lines depends on the soil type; a given soil will always have the same declivity; no matter if the amount of water withdrawn is large or small, the ground-water level will in the end follow a certain declivity toward the place where water is withdrawn.

According to Pennink the degree of declivity in the dunes is 1:200.

It follows that under normal conditions the flow is constant.

If the withdrawal of water is temporary, ground water will resume its original level; with continued withdrawal, it will flow to the place of withdrawal following a given line of declivity.

Direct measurements have given us the approximate form of these lines of declivity. They are, according to the Commission charged with investigating conditions in Amsterdam, elliptical; according to the Commission charged with investigating the effect of the intake of the water conduit in Breda, to be erected in 1891 on the Seterische Heath south and southwest of the local grazing and farm lands, parabolic in that vicinity.

INFLUENCE ON THE GROUND-WATER LEVEL DUE TO THE WITHDRAWAL OF GROUND WATER FOR HUMAN CONSUMPTION

Manner in which waterworks withdraw water from the soil. It is not the aim of this report to discuss the withdrawal of water from streams and rivers. We are here only concerned with such water systems which draw their needs directly from the soil.

Different methods are used for the withdrawal of ground water, depending on circumstances. On the whole, there are two groups of systems.

1. Those which withdraw from the upper layers.
2. Those which withdraw from the deeper layers.

With the first group, open canals are used or wells 8 m. deep and 2 m. wide from where the accumulated water is pumped or, horizontal drainage conduits are laid at various depths.

These stone conduits 50 to 60 cm. in diameter, not quite adjoining, are covered with a layer of porous substances consisting of gravel, shells, or river sand.

These systems are used in Amsterdam, The Hague, and Leiden.

The second system which withdraws water from the deeper layers is the so-called "bronpijpen" system (conduit for the withdrawal of spring water). Vertical conduits ± 10 to 50 cm. wide which withdraw ground water from 10 to 30 m. below A.P.1/ yes, even at a depth of 72 m. as in Nykerk.

1/ A.P. - Amsterdamsch peil. Average height of tide of the "Y" an inlet of the Zuiderzee before its canalization connecting it with the North Sea giving Amsterdam direct access to the North Sea.--Tr.

No matter which system is used, all withdraw water from the soil.

Methods which withdraw water from the upper layers only cause lowering of ground water locally and also cause the ground-water level from the upper surface to the level in the canals, wells, or drains to assume a parabolic or elliptic form following the lines of declivity.

All systems, however, have the same effect, namely, the ground-water level is lowered at points where water is withdrawn causing the ground water to flow in the direction of such points.

The area over which the ground water is lowered is absolutely indefinite and not constant. It depends above all on the amount of water withdrawn. The greater the amount of water withdrawn the greater the distance in which the effect is felt. It is also dependent on the amount of rain.

The greater the supply of water to the soil the less injurious is the influence of withdrawal. The depth at which water is withdrawn also influences the area in which the withdrawal will be noticeable.

The longer we continue to withdraw water the greater the area is influenced.

Finally, the area over which the ground-water level is being lowered depends on the soil type and especially on the location of layers in the soil.

With great and widely fluctuating subterranean differences (which cannot always be examined sufficiently before the installation of conduits) the area over which the ground-water level is lowered will be different. For that reason it is almost impossible to determine beforehand where water will be withdrawn.

The system whereby water is withdrawn from the deeper layers is not initially as intense in its effect as the shallow system, especially if there is a non-penetrative layer below the intake point.

If, for example, the conduit is finally checked by a non-penetrative layer (clay), water will be withdrawn above this point; with the deeper system, for example, down to 20 m., water below the clay layer is utilized and the ground-water level will at first sink little. At a distance, however, or elsewhere where the layer ends, the effect of the deeper system becomes gradually noticeable.

Assuming that ground water flows to the places where it is withdrawn, following lines of declivity of 1/200 to 1/300, every m. deepening of the canals or drains will cause the ground-water level to be lowered over an area extending 200 or 300 m. in all directions.

Consequently, the gradual extension of water works in a given district will cause the effect of withdrawal to be noticed at ever increasing distances.

The lowering of the ground-water level and the extent to which this is influenced by the annual withdrawal of rain water will not be discussed because it is of less importance.

It is, however, fairly safe to say that the bottom of the canals or drains will not continue to correspond to the natural ground-water level and that at times they will have to be deepened.

Increase of water consumption. Of more and greater significance, however, is the fact that precipitation on the original areas proved insufficient.

All water systems show a steady increase of consumption and also that the surface where water is withdrawn must be extended.

The following figures show the increase of water consumption:

Amsterdam		
1856	2,600,000	cu.m.
1889	8,130,000	"
Zwolle		
1893	210,242	"
1899	479,714	"
Breda		
1894	175,075	"
1899	330,147	"

	Utrecht		
1884	....	463,000	cu.m.
1899	....	2,534,916	"
	Zutphen		
1891	....	128,420	"
1899	....	193,843	"
	Arnhem		
1890	....	462,107	"
1900	....	1,000,243	"
	Leiden		
1879	....	109,593	"
1899	....	1,060,247	"
	Harderwijk		
1898	....	20,673	"
1899	....	25,093	"
	The Hague		
1875	....	463,000	"
1899	....	6,968,000	"

As can be seen, there is an ever increasing demand for water and if the supply is no longer adequate it becomes necessary to increase the capacity of the intake usually at great expense. Rain water which helped to swell the volume of ground water is no longer adequate; we utilize more than its maximum capacity.

The capacity of the intake is enlarged either by deepening the canals or drains in which case we draw directly on the ground-water supply or the surface of the intake is extended by digging canals or laying of conduits in new areas.

No matter how the system is extended, if the demand for water keeps on increasing, which is now the case, each expansion will only bring temporary relief because the ground-water level will continue to be lowered to a certain point even if increasing the intake keeps step with increasing consumption.

EFFECT OF THE WITHDRAWAL OF GROUND WATER AND MANNER IN WHICH IT IS FELT

Influence of desiccation on vegetation in and outside the dunes. As stated above, the withdrawal of ground water causes lowering of the ground-water level.

This lowering is initially noticeable within the immediate vicinity of points where water is withdrawn; it will spread according to the amount of water drawn from the soil.

In order to demonstrate the extent in which our profession is able to judge conditions, we attempted to gather as much data as possible in those regions where for years water works have existed and which reveal convincingly that increasing desiccation goes hand in hand with increasing water consumption.

This desiccation is particularly noticeable in the dunes, especially in the vicinity of Amsterdam and The Hague water works where canals spread over a wide area. Desiccation of this dune region is extremely severe.

The visitor is struck by the absence of birch stands while the dunes all along the coast are generally rich in birch stands.

One finds many dune valleys in the vicinity of water works which by their flat bottom, the humus cover, and the remains of earlier vegetation indicate a luxuriant vegetation in the past.

In earlier days before the water works had extended their net of conduits through the dunes, the entire region used to be moist.

D. F. Gevers writes: "In the last 25 years there have been 2 or 3 occasions where people were able to skate through the dunes from Paardenkerhof to Zandvoort." Today, conditions are entirely different.

Before 1875 when the water works of The Hague were beginning to operate, the dunes were in good condition.

Especially the lower flats which where generally grown with birch trees while the lower fields near the villages were converted into arable land.

In those days there were even sporadic crop failures due to high water. In the winter most areas were under water.

When in 1875 the water works started to operate there was at first no injurious effect noticeable since the water surface in the dunes near Wassenaar was 3 m. higher than in Scheveningen.

After this supply was exhausted desiccation became noticeable. First to suffer were the arable lands along the canal while the birch stands started to decline. It was clearly observed that desiccation was spreading over wider areas. This condition was accelerated since from the original canals secondary channels were dug through the dunes enlarging the drainage area.

During the first ten years, lowering of the water surface was not so intense but after that it was much more rapid.

The extension of secondary channels caused the wells near Waals to run dry; after that the wells in Mejendel on the estate of Baron van Pallandt.

Along the road from Wassenaar to the sea are various dune plots which during wet summers remained uncultivated due to high water. Today water is 1 m. lower. So with the dune areas of Count van Stirum, the so-called "Pan van Perseyn".

In earlier days water was plentiful; today water for cattle is carried in tubs. Many land owners are obliged to pump their water into moats dug at the foot of the dunes.

It is interesting to compare this data with water measurements mentioned by Henkel 1/ from which Vuyck 2/ calculated the depth of the

1/ Duinwaterleiding voor 's Gravenhage en Leiden (Water works for the Hague and Leiden). 's Hage 1869, pp.10 and 11.

2/ Vuyck. De plantengroei der duinen (Plant growth in the dunes). p. 185.

water below the lowest intakes in the dune flats. For example, he found for the meadows near Waalsdorp (huis van Greup) 0.65 M.

Meyendel .... 1.10 M.
Sparregat .... 0.75 M. where now the wells are dry.

Another case is the dunes near Haarlem which are now severely desiccated due to the influence of the Amsterdam Water Works established in 1852.

In the Haarlem dunes south of Zandvoort there is a small farm in the center of the dunes called "het Paradijs" (Paradise). Near the homestead is a fairly large plot of grazing land and also many acres of arable land. In earlier days the inhabitants kept 3 to 4 cows. Grass was plentiful and the arable acres yielded a good crop. The meadow is now an arid moss area with some grassy plants.

Dry holes show the places where cattle used to drink. Most of the farm lands have been abandoned. Truly, the name "Paradise" is now scarcely appropriate; "desert" expresses it far better.

All the residents in the small homes on the road from Haarlem to Zandvoort complained that their wells have run dry. These injurious effects are noticeable everywhere, even in the former army field west of Haarlem.

Captain van Elswoud reported that in earlier days it was necessary to dig drainage canals while now the field is completely dry. Many complaints are heard regarding the decrease of the potato crop.

This used to be a source of income for most farmers while today there is only a very modest crop and then only in moist years. Walking through the dunes in the vicinity of the water works one notices many potato fields that have been abandoned.

With regard to the decrease of the potato crop it has often been claimed that this was due to cultivation (see Staring)[1] and also

[1] Natuurkunde en Volksvlijt voor Nederland (Natural science and natural industry for the Netherlands). p. 177.

Vuyck [2] as well as the report of the Amsterdam Commission on p. 71.

[2] De plantengroei der duinen (Plant growth in the dunes) p. 293.

Of course it cannot be denied that the successive raising of potatoes on the same land must become less profitable if we neglect to fertilize.

This is the reason why the Amsterdam Commission came to its conclusion, because it took only the dunes near Zandvoort into consideration where the soil was of very good quality. In Noordwijk where the soil is also rich, cultivation may be carried on for some years but elsewhere, for example, near the Hague and Wassenaar, it was always necessary to fertilize the fields intensely and often, even before the water works were established, in order to obtain a meagre crop. Among the dune water works which have been very detrimental belongs, above all, the Leiden Works near Katwyk. Its injurious effect is particularly responsible for the decrease of the potato crop which used to be a principal source of income for the inhabitants. Today one observes numerous parcels of land which previously were potato lands but which are now abandoned. The soil has dried and is no longer suitable for agriculture. Land owners report that rentals for their potato fields have been reduced considerably. It is their opinion that the decrease of the potato crop has been a serious blow to the local population.

Soon the intake of the Leiden Water Works will be lengthened as far as Berkheide. When that is done only a small strip of dunes will separate the Hague Water Works from Leiden. Desiccation will then become very severe in this part of the dunes. The ground-water level in the entire dune area, from Scheveningen to the Katwyk canal, will be lowered considerably.

Desiccation of the dunes near Schoorl is also noticeable and is caused by the Alkamaar Water Works. These works were erected in 1885 and at first used the canal system. The increase of water consumption, however, made changes necessary. In 1896, 10 vertical conduits were laid below the intake which is ± 30 M. below A. P. Desiccation is now very severe.

Pools and small lakes which only 6 years ago had water, even in the summer, are now dry and those which still have water have been reduced to tiny pools which diminish from year to year. Furthermore 30-to 50-year-old trees growing in the flats have suffered also while trees such as Picea rubra with shallow roots are dying slowly.

But also outside the dunes the diminishing water supply has become noticeable.

The brook near Aagtdorp was never dry in 1894, 1895, and 1896, not even in the summer, while the last year it was completely dry during the summer and even in the winter had little water. The same has been observed in other regions.

Another re ort from Bergen states that many cellars which 15 or 18 years ago had from 1/2 to 1-1/2 ft. of water now remain completely dry.

All reports concerning desiccation which have come to my notice are for the last 15 years so that there cannot be any question about it that the water works are responsible.

Earlier observations concerning the desiccation of the dunes. It will be necessary to draw attention to another occurrence which heretofore had remained an open question but which seems to have some relation to the desiccation of the dunes. If we were to look up all the literature of the last century and the beginning of this one we learn that desiccation of the dunes was being observed.

For example, we find in the report [1] p.113 by the Commission

[1] See Vuyck. Plant growth in the dunes, p. 173.

of Superintendency charged with investigating the dunes in what was formerly called the Hollandsch Gewest: "During all of our inspections, in the north as well as the south, the most experienced people reported unanimously that for the last 10 years water in the flats has been diminishing."

We have been shown places which previously were inundated with from 2 to 3 ft. of water and which used to be enormous ice fields for winter sport but which now are only swampy during the winter.

Twent van Raaphorst [2] reports on the flat of van Berkhey:

[2] Wandeling door de Zeeduinen, van Wassenaar tot dicht aan Scheveningen (Wandering through the sea-dunes from Wassenaar to Scheveningen).

"What is characteristic of this area is that now for the last three years there has been no water in this low land nor in any other dune

flats, whereas in early days there always used to be plenty of water even in the summer."

Gevers writing about the dunes states:[1] "Everywhere I asked

[1] Treatise published by the Maatschappij ter bevordering van den Landbouw, te Amsterdam, XVIII part 1826, p.20.

I was assured that water used to be plentiful everywhere."

The above quotations show that in the beginning of this century moisture decreased considerably yet we must not lose sight of the fact that in those days there occurred several dry and several wet years.

All of Gervers' data refer to the wet years of 1816 and 1817 and for 1823 when precipitations were extremely heavy in the spring after an extraordinarily dry summer and fall during the preceding year. Over a long period the influence on the water level due to some dry and wet years is neutralized. It has been shown in all the old literature that there had been some desiccation of the dunes in those days. The fact remains that conditions were entirely different from what they are now. There can not be any question about it that beside the water works there were other contributing causes for the desiccation of the dunes, namely, the digging of large canals through the dunes such as the Noordzeekanaal, the Katwykkanaal, the Scheveningenkanaal, the Zanderyvaart near Haarlem, etc.

Vuyck writes that the desiccation of the dunes is also caused by the shifting of sands which filled the flats and although sand drifting no longer occurs in dunes, new flats are no longer formed. The formation of soil on the flats amount, according to Vuyck, to ± 5 mm. per year.[2]

[2] Vuyck. Plant growth in dunes, p.186, etc.

The general desiccation in places where no canals have been dug either for water works or shipping remains, therefore, an open question although it must be admitted that desiccation caused by transportation canals is not very severe, while desiccation caused by water works is very striking, particularly so when new areas are being utilized and new canals are dug, or when existing open canal systems are deepened.

Lowering of the ground-water level elsewhere. In the meantime, the injurious effects due to withdrawal of ground water by water works is not only noticeable in the dunes but also with water works located inland.

For example, a local investigation of conditions near the intake of the Utrecht Water Works in Soesterberg revealed the harm caused by the lowering of the ground-water level in that area. This influence is,

however, only noticeable in the area north of the intake and must be ascribed to the fact that this terrain slopes in a northern direction. Consequently, withdrawal of the ground water interrupted the flow of ground water from the higher to the lower ground. Hence, the areas below the intake are now deprived of part or all the water pressure from higher grounds.

The influence of the withdrawal of water is felt over an area as far as the village of den Buld which is from 2,200 to 2,500 m. in a straight line from the intake, while the village of Soesterberg escaped.

The residents of a dwelling house about 800 m. north of the intake claim that in earlier days during the wet season there was always too much water. They had to lay planks from their home to the road while in the past year, which was comparatively rainy, the wells had run dry.

For many years this well had plenty of water which diminished gradually and in 1900 ran completely dry.

The farms suffered little in earlier days; the crops were always plentiful while now they are only satisfactory in moist years; there is a complete crop failure during dry years.

There is complaint about contamination of water, something which never happened earlier. The cause of this must probably be looked for in the fact that the inhabitants no longer received subterranean water flowing from high altitudes. There developed a different flow of the ground water which causes contamination.

The desiccation reveals itself not only in the manner described above but the farmers too are affected. In spite of more intensive fertilization their acres yield less than before.

Previously they were able to cultivate better crops with little fertilization, better than now possible with intensive working of the soil. The ground-water level has been lowered so much and water is withdrawn so rapidly that the plants are unable to use it and the effect of fertilization is almost negligible. Earlier in this paper we referred to the same occurrence in regard to the potato fields in the dunes. In fact if we stop to consider that the ground-water level has been lowered so much that it affected the wells it should surprise no one that the condition of farm lands in that vicinity must have changed also.1/

1/Water works which use the artesian system soon notice the lowering of the ground-water level near the intake; the injurious effects, however, are manifested much later. All of these systems, however, are of later date. For example, in Utrecht where a mixed system is in

(Cont'd.)

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operation the ground-water level near the intake in Soestersberg has been lowered since 1883 from 5.88 m. above A P (maximum) and 5.21 m. above A P (minimum) to 4.60 m. and 4.22 m. above A P in 1899. The Zwolle Water Works dates from 1893. In that year the ground-water level in the different control wells revealed an average of 11.90 m. above A P; in 1900 the highest water level averaged 10.54 above A P. These systems have been in operation for a short time only and the fact that water is drawn from the deeper layers only makes it but natural that the injurious effect will be felt much later.

General remarks regarding Government regulations. With respect to damage to third parties caused by the water works it is our conviction that laws should be enacted which will correct this injury.

Of course it will be difficult to make regulations which will be retroactive so that many who have already suffered cannot expect compensation. On the other hand, it is our opinion that we should not lose sight of the fact that the increasing demands made on the water works will in the end aggravate the conditions. We refer to the Hague Water Works where at a distance of a few hundred meters from the foot of the dunes the conduits have been laid so deep that it is unavoidable that water will have to be drawn from the flats.

Since we have no laws restricting the depth at which conduits may be laid nor the distance from the foot of the dunes, the towns, due to the ever increasing demand for water, certainly won't hesitate to exploit the area at their disposal in the most intensive manner.

In this respect we refer once more to the water works in Soest. What is going to happen if there too the net of conduits are steadily extended?

True, we admit that with regard to the smaller communities the lack of large enough areas for the withdrawal of water is not a serious problem. It is, however, a serious question insofar as our larger centers of population are concerned so that in this respect we may well ask ourselves what the future holds for our larger cities.

Will they always be able to find adequate water supplies in the areas now exploited, and even if so, will damages to third parties be increasingly severe?

We have seen that the cost of other systems, for example, pumping of water into the dunes and utilizing the dunes as a natural filter, is prohibitive and can only be considered in an extreme emergency.

It is our opinion that an act governing the withdrawal of ground water remains desirable, particularly so since the present statutes of our civil code are inadequate. The validity of our present civil acts, either Article 625 or 626 has, so far as we know, never been

tested, mainly because it is very problematical whether a judge would grant any damages.

As matters now stand every land owner can legally withdraw ground water from his neighbors' property. True, when our civil statutes were written there were no water works. When water was to be drained it was then a matter of improving the soil.

Had the damage due to the withdrawal of ground water been known it is certain that regulations would have been enacted prohibiting one owner from drawing water artificially from higher land owned by someone else.

This, we believe, is the reason why no changes were made in our civil statutes; this, plus the fear of injury to hygienic interests of our larger cities.

If now it is proposed to make changes in our civil statutes, this should not be interpreted to mean obstacles in the path of new water works. On the contrary, good drinking water for our cities is the business of the Government as well as of the communities. No one is going to deny this. But that does not necessarily mean that the rights of third parties shall be completely eliminated.

Small interests will have to make way for larger ones. For our larger cities, and so long as other means are unknown, the withdrawal of pure ground water is a matter of life.

But to violate the rights of innocent outsiders wilfully is an illegal act.

Summary

1. All water systems which draw water from the soil, no matter by what method, lower the ground-water level and change the direction of flow.

2. The area affected depends upon the amount of water withdrawn.

3. It is impossible to define the exact area affected by the lowering of the ground-water level, not even for a certain period.

4. Lowering of the ground-water level will be disadvantageous to those plants which because of their character or diminutive root system need ground water or receive their water from layers which by capillary action were enriched with ground water.

5. Plants which because of their character or because of their roots are accommodated by the amount of water in the upper layers where precipitation is the only replenishing source, are not affected, or at least will not experience any serious harm if from their earlier existence on they were deprived of ground water.

6. Most tree species, especially those selected as suitable for forestation in the dunes or on sandy soils, find sufficient water in the upper layers; their root system enables them to find water over a wide area. The development of the root system must, however, conform permanently to this condition.

   Consequently, plants already existing may experience harm whereas new plantations will not suffer; at the most, forestation of areas exploited by water works will be made more difficult but not impossible.

7. It is desired that laws be enacted regulating the withdrawal of water in such quantities that third parties will not suffer.

8. Until such legislation is enacted, the government must refuse to grant concession for the erection of water works on government lands without first having expert advice whereby the results of water utilization are thoroughly investigated with regard to possible damages to third parties.